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- [ ] Fee Transmittal Form
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- [x] Amendment / Response
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- [ ] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [ ] Response to Missing Parts/ Incomplete Application
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- [ ] Status Letter
- [x] Other Enclosure(s) *(please identify below)*:
  - **Verified Translation of JP 09-253972**
  - **Return receipt postcard**

Remarks: **The Commissioner is hereby authorized to charge any additional fees that may be required under 37 CFR 1.16 or 1.17 to Deposit Account No. 08-0750. A duplicate copy of this sheet is enclosed.**

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

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Date	October 16, 2003		

CERTIFICATE OF MAILING/TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Director of the U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450, or facsimile transmitted to the U.S. Patent and Trademark Office on the date indicated below.

Typed or printed name	G. Gregory Schivley Bryant E. Wade		
Signature	G. Gregory Schivley	Date	October 16, 2003

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.:	09/607,017
Filing Date:	06/29/2000
Applicant:	Chiyoaki Iijima
Group Art Unit:	2871
Examiner:	Prasad R. Akkapeddi
Title:	DISPLAY DEVICE AND ELECTRONIC APPARATUS EMPLOYING THE SAME
Attorney Docket:	9319S-000073/COA

Director of the United States Patent and Trademark Office
P.O. Box 1450
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SUPPLEMENTAL RESPONSE

Sir:

Further to applicant's response filed September 16, 2003, and in particular in support of applicant's argument with respect to the 102(e)/103 argument, enclosed is a verified translation of JP09-253972 (the priority document for this application).

Should the examiner have any questions, please feel free to telephone the undersigned.

Respectfully submitted,

Dated: Oct 16, 2003

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CERTIFICATE

I, Keiko NAOI, residing at 1-22-19, Shonan-Village, Yokosuka-shi, Kanagawa-ken, 240-0107 Japan, hereby certify that I am the translator of the attached document, namely a Certified Copy of Japanese Patent Application No. 9-253972 and certify that the following is a true translation to the best of my knowledge and belief.

K. Naoi
Signature of Translator

September 22, 2003
Date

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[Reference No.]	P0S59063
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[The Number of Claims]	13
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[Name of Document] SPECIFICATION

[Title of the Invention] DISPLAY APPARATUS AND ELECTRONIC EQUIPMENT USING THE SAME

[Claims]

[Claim 1] A display apparatus comprising:

a transmissive polarizing axis variable unit for varying a transmissive polarizing axis;

first and second polarization splitting units disposed on both sides of the transmissive polarizing axis variable unit with the intermediary of the transmissive polarizing axis variable unit; and

a light dispersing unit disposed on the opposite side of the transmissive polarizing axis variable unit relative to the second polarization splitting unit,

wherein the first polarization splitting unit is a polarization splitting unit allowing a linearly polarized light component in a first predetermined direction of a light beam incoming from one side of the first polarization splitting unit to pass therethrough and to be emitted from the other side located on the opposite side from the one side, and allowing a linearly polarized light component in the first predetermined direction of a light beam incoming from the other side to pass therethrough and to be emitted from the one side, and

wherein the second polarization splitting unit is a

polarization splitting unit allowing a linearly polarized light component in a second predetermined direction of a light beam incoming from the side of the transmissive polarizing axis variable unit to pass therethrough and to be emitted toward the light dispersing unit and reflecting a linearly polarized light component in a third predetermined direction, which is different from the second predetermined direction, of the same toward the transmissive polarizing axis variable unit, and allowing a linearly polarized light component in the second predetermined direction of a light beam incoming from the side of the light dispersing unit to pass therethrough and to be emitted toward the transmissive polarizing axis variable unit.

[Claim 2] A display apparatus according to Claim 1, characterized in that a light source is arranged on the opposite side of the light dispersing unit relative to the second polarization splitting unit.

[Claim 3] A display apparatus according to any one of Claims 1 to 2, characterized in that the light dispersing unit comprises a unit for reflecting a light beam on the opposite side of the light dispersion unit relative to the second polarization splitting unit.

[Claim 4] A display apparatus according to any one of Claims 1 to 3, further comprising a third polarization splitting unit on the opposite side of the light dispersing

unit relative to the second polarization splitting unit,

characterized in that the third polarization splitting unit is a polarization splitting unit allowing a linearly polarized light component in a fourth predetermined direction of a light incoming from the side of the light dispersing unit to pass therethrough and allowing a linearly polarized light component in a fifth predetermined direction, which is different from the fourth direction, of the same to reflect toward the light dispersing unit, and allowing a linearly polarized light component in the fourth predetermined direction of a light incoming from the opposite side of the light dispersing unit to pass therethrough and to be emitted to the light dispersing unit.

[Claim 5] A display unit according to any one of Claims 1 to 4, characterized in that the second polarization splitting unit is a polarization splitting unit allowing a linearly polarized light component of the second predetermined direction of a light incoming from the side of the transmissive polarizing axis variable unit in the range of almost all wavelengths within a visible light range to pass therethrough and to be emitted toward the light dispersing unit, and reflecting a linearly polarized light component in the third predetermined direction, which is different from the second predetermined direction, of the same toward the transmissive polarizing axis variable unit,

and allowing a linearly polarized light component in the second predetermined direction of a light beam incoming from the side of the third polarization splitting unit in the range of almost all wavelengths within the visible light range to pass therethrough and to be emitted toward the transmissive polarizing axis variable unit.

[Claim 6] A display apparatus according to any one of Claims 1 to 5, characterized in that the transmissive polarizing axis variable unit is a liquid crystal panel.

[Claim 7] A liquid crystal display apparatus according to Claim 6, characterized in that the transmissive polarizing axis variable unit is a TN liquid crystal panel, an STN liquid crystal panel, or an ECB liquid crystal panel.

[Claim 8] A display unit according to any one of Claims 1 to 7, characterized in that the first polarization splitting unit is a polarizer.

[Claim 9] A display apparatus according to any one of Claims 1 to 8, characterized in that an angle formed between the second predetermined direction and the fourth predetermined direction is between 45 and 80 degrees.

[Claim 10] A display apparatus according to any one of Claims 1 to 8, characterized in that an angle formed between the second predetermined direction and the fourth predetermined direction is between 60 and 75 degrees.

[Claim 11] A display apparatus according to any one of

Claims 1 to 10, characterized in that the second polarization splitting unit is a laminated piece including a plurality of layers laminated so as to be in intimate contact with each other, and the refractive indexes of the adjacent two layers are the same in the sixth predetermined direction, and are different from each other in the seventh predetermined direction, which is different from the sixth predetermined direction.

[Claim 12] A display unit according to any one of Claims 4 to 11, characterized in that the third polarization splitting unit is a laminated piece including a plurality of layers laminated so as to be in intimate contact with each other, and the refractive indexes of the adjacent two layers are the same in the eighth predetermined direction, and are different from each other in the ninth predetermined direction, which is different from the eighth direction.

[Claim 13] Electronic equipment characterized in that the display apparatus according to any one of Claims 1 to 12 is provided.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a display apparatus and electronic equipment and, more specifically to a transflective liquid crystal display apparatus.

[0002]

[Description of the Related Art]

In a liquid crystal display apparatus such as a TN (Twisted Nematic) liquid crystal, a STN (Super-Twisted Nematic) liquid crystal, and the like, in which a transmissive polarizing axis variable optical element for rotating a polarizing axis of in the related art is used, a construction such that the transmissive polarizing axis variable optical element is interposed between two polarizers is employed. Therefore, the usability of light is not good, and especially when a transflective type is employed, there is a problem in that the display becomes dark in the reflecting mode.

[0003]

Referring now to Fig. 1, a transflective type of the related art employing the TN liquid crystal panel as a transmissive polarizing axis variable means will be described. Fig. 1 is a cross-sectional view of a transflective display apparatus in the related art. Reference numeral 130 designates an upper polarizer, reference numeral 140 designates a TN liquid crystal panel, reference numeral 170 designates a lower polarizer, reference numeral 180 designates a transflective plate, and reference numeral 210 designates a light source. Although the respective components are shown to be away from each

other in Fig. 1 for the sake of clarification, they are actually disposed so as to be in intimate contact with each other.

[0004]

A white display at the time of the reflecting mode will be described. A light beam shown in a light path 111 is transformed into a linearly polarized light being parallel with the plane of the drawing at the upper polarizer 130, and then twisted in direction of polarization by 90° at the TN liquid crystal panel 140, thereby becoming a linearly polarized light vertical to the plane of the drawing. Subsequently, it is passed through the lower polarizer 170 in a state of the linearly polarized light vertical to the plane of the drawing as is, and then reflected by and partly passed through the transflective plate 180. The reflected part of the light beam is passed through the lower reflector 170 in a state of the linearly polarized light vertical to the plane of the drawing as is, and then twisted in direction of polarization by 90° at the TN liquid crystal panel 140 and is transformed into a linearly polarized light being parallel with the plane of the drawing before being emitted from the upper polarizer 130.

[0005]

When such transflective display apparatus is used, since the lower polarizer 170 is polarization splitting

means associated with absorption, part of the light beam is absorbed when the light beam passes through the lower polarizer 170 twice. Therefore, usability of light is not good, and there is a problem in that the display becomes dark when in the reflecting mode.

[0006]

Therefore, the inventors of the present invention proposed a transflective display apparatus using a polarization splitter which reflects a linearly polarized light component in a predetermined direction and allows transmission of a linearly polarized light component in the direction vertically thereto instead of the lower polarizer on the side of the light source (Japanese Patent Application No. 8-245346). Referring now to Fig. 2, a transflective display apparatus employing the polarization splitter will be described.

[0007]

In Fig. 2, reference numeral 120 designates a voltage-free portion of the TN liquid crystal panel, and reference numeral 110 designates a voltage-applied portion of the TN liquid crystal panel.

[0008]

Reference numeral 130 designates the upper polarizer, reference numeral 302 designates an upper glass substrate, reference numeral 304 designates a lower glass substrate,

reference numeral 160 designates a polarization splitter, reference numeral 307 designates a transflective light absorbing layer, and reference numeral 210 designates a light source.

[0009]

In a first place, a white and black display in the deflective display mode will be described. A light beam shown in a light path 601 incoming from the outside the display apparatus is transformed into a linearly polarized light being parallel with the plane of the drawing at the upper polarizer 130, and is twisted in direction of polarization by 90° at the voltage-free portion 120 of the TN liquid crystal panel into a linearly polarized light in the direction vertical to the plane of the drawing. Subsequently, it is reflected by the polarization splitter 160 in the state of linearly polarized light in the direction vertical to the plane of the drawing as is, and is twisted again in direction of polarization by 90° at the voltage-free portion 120 of the NT liquid crystal panel into a linearly polarized component being parallel with the plane of the drawing before being emitted from the upper polarizer 130. Therefore, when no voltage is applied on the TN liquid crystal panel, the display is displayed in the white display mode. In this manner, since the light beam of the white display is the light beam reflected at the polarization

splitter 160, the display is brighter than the transflective display apparatus in the related art. The light beam shown in a light path 603 is transformed into a linearly polarized light being parallel with the plane of the drawing at the upper polarizer 130, is passed through the voltage-applied portion 110 of the TN liquid crystal panel in a state of linearly polarized light being parallel with the plane of the drawing as is without changing the direction of polarization, is passed again through the polarization splitter 160 as is without changing the direction of polarization, and then is absorbed into the transflective light absorbing layer 307, whereby the display is displayed in the black display mode.

[0010]

On the other hand, when in the transmitting mode, a light beam shown in a light path 602 is passed through an opening formed on the transflective light absorbing layer 307, is transformed at the polarization splitter 160 into a linearly polarized light being parallel with the plane of the drawing, twisted in direction of polarization by 90° at the voltage-free portion 120 of the TN liquid crystal panel into a linearly polarized light vertical to the plane of the drawing, and is absorbed by the upper polarizer 130, whereby the display is displayed in the black display mode. A light beam shown in a light path 604 is passed through the opening

formed on the transflective light absorbing layer 307, is transformed into a linearly polarized light being parallel with the plane of the drawing at the polarization splitter 160, and is passed through the voltage-applied portion 110 of the TN liquid crystal panel and then the upper polarizer 130 in a state of a linearly polarized light being parallel with the plane of the drawing as is without changing the direction of polarization, whereby the display is displayed in the white display mode.

[0011]

[Problems to be Solved by the Invention]

However, when such polarization splitter is employed, there arises such phenomenon that the positive-negative relation of the display is inverted between the transmissive display and the reflective display, and thus it may not be suitable for some applications.

[0012]

It is an object of the present invention is to provide a display apparatus employing a transmissive polarizing axis variable optical element, wherein a bright display is presented without inversion between positive and negative both in the reflecting mode which uses outside light and in the transmitting mode which uses illumination of the light source and, in addition, to provide electronic equipment using the same.

[0013]

[Means for Solving the Problems]

Referring now to Fig. 3, Fig. 4, and Fig. 5, the principle of the invention will be described. Fig. 3 is a schematic perspective view of a polarization splitter used as polarization splitting means, Fig. 4 is an explanatory drawing of a case in which outside light is entered into the display apparatus having the polarization splitter, and Fig. 5 is an explanatory drawing of a case in which a light source is illuminated.

[0014]

In Fig. 3, the polarization splitter 160 has a construction in which a plurality of two different types of layers 1 (layer A) and 2 (layer B) are laminated alternately. The refractive index of the layer A1 in a direction X (nAX) differs from the refractive index of the layer A1 in a direction Y (nAY). The refractive index of the layer A1 in the direction Y (nAY) is substantially the same as refractive index of the layer B2 in the direction Y (nBY).

[0015]

Therefore, the linearly polarized light in the direction Y of the light beams entered into the polarization splitter 160 from the direction vertical to an upper surface 5 of the polarization splitter 160 is passed through the polarization splitter 160 and then is emitted from a lower

surface 6 as a linearly polarized light in the direction Y. ON the other hand, the linearly polarized light in the direction Y of the light beam entered into the polarization splitter 160 is passed through the polarization splitter 160 and is emitted from the upper surface 5 as the linearly polarized light in the direction Y. The direction Y, which is the direction of transmission, will be referred to as transmission axis, hereinafter.

[0016]

On the other hand, assuming that the thickness of the layer A1 in a direction Z is represented by tA, the thickness of the layer B2 in the direction Z is represented by tB, and the wavelength of the incident light is represented by λ:

[0017]

When the expression shown below;

[Expression 1]

$$tA \times nAX + tB \times nBX = \lambda/2 \quad (1)$$

is established, the linearly polarized light in the direction X of the light beam of λ in wavelength, entered into the polarization splitter 160 from the direction vertical to the upper surface 5 of the polarization splitter 160, is reflected by the polarization splitter 160 as the linearly polarized light in the direction X. On the other hand, the linearly polarized light of λ in wavelength,

entered into the lower surface 6 of the polarization splitter 160, is reflected by the polarization splitter 160 as the linearly polarized light in the direction X. The reflecting direction X is referred to as reflecting axis, hereinafter.

[0018]

By varying the thickness tA of the layer A1 in the direction Z and the thickness tB of the layer B2 in the direction Z so that the aforementioned expression (1) is established over the entire range of wavelengths of visible light, a polarization splitter, which reflects the linearly polarized light in the direction X not only of a single color, but also of the entire white light, is reflected as the linearly polarized light in the direction X, and allows the linearly polarized light in the direction Y to pass therethrough as the linearly polarized light in the direction Y, may be obtained.

[0019]

The layer A of the polarization splitter 160 may be formed of a drawn layer of polyethylene naphtalate (PEN) and the layer B may be formed of copolyester of naphtalen dicarboxylic acid and terephthallic or isothalic acid (coPEN). As a matter of course, material of the polarization splitter that can be used in the present invention is not limited thereto, and may be selected as

appropriate. Such polarization splitter is disclosed in detail as a reflective light polarizer in PCT Japanese Translation Patent Publication No. 9-506985.

[0020]

Fig. 4 is an explanatory drawing of a case in which outside light is entered into the display apparatus employing the polarization splitter 160. In this liquid crystal display apparatus, the TN liquid crystal panel 140 is used as transmissive polarizing axis variable optical element. There is the polarizer 130 provided on the upper side of the TN liquid crystal panel 140. On the lower side of the TN liquid crystal panel 140, there are provided the polarization splitter 160, a light dispersing layer 150, a light source 190, and a reflecting layer 200 in this order. The transmission axis of the polarizer 130 and the transmission axis of the polarization splitter 160 are orthogonal with respect to each other.

[0021]

At the voltage applied portion 110 on the right side, a natural light beam 121 is transformed by the polarizer 130 into a linearly polarized light being parallel with the plane of the drawing, then is passed through the TN liquid crystal panel 140 without changing the direction of polarization. Then, it is reflected by the polarization splitter 160 as the linearly polarized light being parallel

with the plane of the drawing, and subsequently, is passed through the TN liquid crystal panel 140 without changing the direction of polarization, and is emitted from the polarizer 130 as the linearly polarized light being parallel with the plane of the drawing. In this manner, when a voltage is applied, the light beam incoming into the polarization splitter 160 is not absorbed, but reflected thereby, and a reflected light beam 122 from the polarization splitter 160 becomes like a mirror surface. Since it is like a mirror surface, it is bright only in the direction of the outgoing angle, which is equal to the incident angle, but dark in other directions.

[0022]

In the voltage-free portion 120 on the left side, a natural light beam 111 is transformed by the polarizer 130 into a linearly polarized light being parallel with the plane of the drawing, and subsequently, is twisted in direction of polarization by 90° by the TN liquid crystal panel 140 into a linearly polarized light in the direction vertical to the plane of the drawing, and then is passed through the polarization splitter 160. The linearly polarized light emitted from the polarization splitter 160 is dispersed at the dispersing layer 150, and is partly reflected and is partly allowed to pass through. The portion of the light beam, which has passed through, is

reflected by the reflecting layer 200, and is dispersed by the dispersing layer 150. The light beam dispersed at the dispersing layer 150 is twisted in direction of polarization by 90° by the TN liquid crystal panel 140, is passed therethrough as a linearly polarized light being parallel with the plane of the drawing, and is emitted from the polarizer 130 as a linearly polarized light being parallel with the plane of the drawing. Since the light beam emitted from the polarizer 130 is a dispersed light, it is white in all directions.

[0023]

In this manner, in the voltage-applied portion 110, the light beam reflected by the polarization splitter 160 is emitted as a mirror surface like light beam 122, and in the voltage-free portion 120, the light beam passed through the polarization splitter 160 is emitted as a light beam 112, which is white in all directions, due to the presence of the dispersing layer 150. Therefore, under outside light, a dark (black) positive display on a white background is presented in most of the directions. However, a positive display like a mirror surface on the white background is presented only in a certain direction.

[0024]

Referring now to Fig. 5, the liquid crystal display apparatus is the same as in Fig. 4. In the voltage-applied

portion 110 on the right side, the light component in the direction of the transmission axis of the polarization splitter 160 of a light beam 125 from the light source is passed through the polarization splitter 160 as a linearly polarized light vertical to the plane of the drawing. The light beam passed therethrough passes again through the TN liquid crystal panel 140 without changing the direction of polarization, and is transformed into a linearly polarized light, which is vertical to the plane of the drawing, and is absorbed by the polarizer 130. In other words, the light beam becomes darker.

[0025]

In the voltage-free portion 120 on the left side, the light component in the direction of the transmission axis of the polarization splitter 160 of the light beam 115 from the light source is passed through the polarization splitter 160 as a linearly polarized light vertical to the plane of the drawing. The light beam passed therethrough is twisted in direction of polarization by 90° by the TN liquid crystal panel 140, passes therethrough as a linearly polarized light being parallel with the plane of the drawing, and is emitted from the polarizer 130 as a linearly polarized light being parallel with the plane of the drawing.

[0026]

In this manner, when the light source is illuminated,

the light beam is absorbed by the polarizer 130 and thus gets dark in the voltage-applied portion 110, while the light beam is passed through the polarizer 130 and thus becomes brighter in the voltage-free portion 120. Therefore, under the illumination of the light source 190, a black positive display on the background of the color of the light source is presented.

[0027]

In other words, either under outside light or under the illumination of the light source, the positive display is presented.

[0028]

Though the TN liquid crystal panel 140 has been described as an example in the description described above, the basic principle of operation is the same even when those in which the transmissive polarizing axis can be varied by a voltage, such as a STN liquid crystal panel or an ECB (Electrically Controlled Birefringence) liquid crystal panel, are employed instead of the TN liquid crystal panel 140.

[0029]

The present invention is based on the above-described principle, and according to the present invention, a display apparatus including:

a transmissive polarizing axis variable unit for varying a transmissive polarizing axis;

first and second polarization splitting units disposed on both sides of the transmissive polarizing axis variable unit with the intermediary of the transmissive polarizing axis variable unit; and

a light dispersing unit disposed on the opposite side of the transmissive polarizing axis variable unit relative to the second polarization splitting unit,

wherein the first polarization splitting unit is a polarization splitting unit allowing a linearly polarized light component in a first predetermined direction of a light beam incoming from a first side of the first polarization splitting unit to pass therethrough and to be emitted from a second side located on the opposite side from the first side, and allowing a linearly polarized light component in the first predetermined direction of a light beam incoming from the second side to pass therethrough and to be emitted from the first side, and

wherein the second polarization splitting unit is a polarization splitting unit allowing a linearly polarized light component of a second predetermined direction of a light beam incoming from the side of the transmissive polarizing axis variable unit to pass therethrough and to be emitted toward the light dispersing unit and reflecting a linearly polarized light component in a third predetermined direction, which is different from the second predetermined

direction, of the same toward the transmissive polarizing axis variable unit, and allowing a linearly polarized light component in the second predetermined direction of a light beam incoming from the light dispersing unit to pass therethrough and to be emitted toward the transmissive polarizing axis variable unit.

[0030]

Preferably, a display apparatus characterized in that a light source is arranged on the opposite side of the light dispersing unit relative to the second polarization splitting unit.

[0031]

In a display apparatus according to the present invention, under outside light, two display states including a first display state like a mirror surface formed by a light beam reflected from the second polarization splitting unit and a second display state formed by a dispersed light beam from the light dispersing unit are presented depending on the state of the transmissive polarizing axis of the transmissive polarizing axis variable unit. In the first display state, the display becomes dark in the directions other than the direction of the outgoing angle, which is equal to the incident angle of the light beam, and becomes like a mirror surface only in the direction of the outgoing angle, which is equal to the incident angle of the light

beam. In the second display state, the light beam is dispersed and thus becomes bright in all directions. When the light source is illuminated, two display states including a third display state in which the light beam is not passed through the first polarization splitting unit and a fourth display state formed by the light beam passed through the first polarization splitting unit are presented depending on the state of the transmissive polarizing axis of the transmissive polarizing axis variable unit.

[0032]

Since the second polarization splitting unit is not associated with absorption of light beams, a bright positive display is presented both in the reflecting mode and the transmitting mode in the transflective display.

[0033]

Preferably, a unit for reflecting a light beam is provided on the opposite side of the light dispersion unit relative to the second polarization splitting unit. In this arrangement, the display becomes further brighter both in the reflecting mode and the transmitting mode.

[0034]

In addition, a third polarization splitting unit is provided on the opposite side of the light dispersing unit relative to the second polarization splitting unit, and the third polarization splitting unit is a polarization

splitting unit allowing a linearly polarized light component in a fourth predetermined direction of a light incoming from the side of the light dispersing unit to pass therethrough and allowing a linearly polarized light component in a fifth predetermined direction, which is different from the fourth direction, of the same to reflect toward the light dispersing unit, and allowing a linearly polarized light component in the fourth predetermined direction of a light incoming from the opposite side of the light dispersing unit to pass therethrough and to be emitted toward the light dispersing unit. In this arrangement, the display may be made brighter in the reflecting mode.

[0035]

Preferably, the second polarization splitting unit is a polarization splitting unit allowing a linearly polarized light component of the second predetermined direction of a light incoming from the side of the transmissive polarizing axis variable unit in the range of almost all wavelengths within a visible light range to pass therethrough and to be emitted toward the light dispersing unit and reflecting a linearly polarized light component in the third predetermined direction, which is different from the second predetermined direction, of the same toward the transmissive polarizing axis variable unit, and allowing a linearly polarized light component in the second predetermined

direction of a light beam incoming from the side of the third polarization splitting unit in the range of almost all wavelengths within the visible light range to pass therethrough and to be emitted toward the transmissive polarizing axis variable unit.

[0036]

In this arrangement, in the second display state, a white reflection is presented.

[0037]

As the transmissive polarizing axis variable unit, a liquid crystal element is preferably used, and more preferably, the TN liquid crystal panel, the STN liquid crystal panel, or the ECB liquid crystal panel is used. The STN liquid crystal panel includes an STN liquid crystal panel using an optical anisotropic body for color compensation.

[0038]

In addition, the first polarization splitting unit is preferably a polarizer.

[0039]

Furthermore, an angle formed between the second predetermined direction and the fourth predetermined direction is preferably between 45 and 80 degrees and, more preferably, between 60 and 75 degrees.

[0040]

In this arrangement, both when the light source is illuminated and when outside light is incoming, a bright display is presented.

[0041]

The second polarization splitting unit is a laminated piece including a plurality of layers laminated so as to be in intimate contact with each other, and the refractive indexes of the adjacent two layers are the same in the fifth predetermined direction, and are different from each other in the sixth predetermined direction, which is different from the fifth predetermined direction.

[0042]

The third polarization splitting unit is a laminated piece including a plurality of layers laminated so as to be in intimate contact with each other, and the refractive indexes of the adjacent two layers are the same in the seventh predetermined direction, and are different from each other in the eighth predetermined direction, which is different from the seventh direction.

[0043]

Furthermore, the electronic equipment of the present invention is provided with the display apparatus according to Claim 1 mounted thereon. Depending on its application, any one of above-described types of display apparatus may be mounted.

[0044]

In the display apparatus according to the present invention, an active element such as a TFT or a MIM may be provided.

[0045]

[Description of the Embodiments]

Referring now to the drawings, an embodiment of the present invention will be described.

[0046]

(First Embodiment)

Fig. 6 is an explanatory exploded cross-sectional view showing a liquid crystal display unit according to a first embodiment of the present invention.

[0047]

In a liquid crystal display apparatus 10 according to the present embodiment, an STN panel 20 is used as a transmissive polarizing axis variable optical element. On the upper side of the STN panel 20, a phase different film 14 and a polarizer 12 are provided in this order. On the lower side of the STN panel 20, the polarization splitter 40, a dispersing plate 30, a light source 70, and a reflector plate 90 are provided as a polarization splitting unit in this order. The polarization splitter 40 used here is the polarization splitter, which has described as a polarization splitting unit in conjunction with Fig. 3.

[0048]

In the STN panel 20, a STN liquid crystal 26 is encapsulated in a panel constructed of two glass substrates 21, 22 and a sealing member 23. A transparent electrode 24 is provided on the lower surface of the glass substrate 21, and a transparent electrode 25 is provided on the upper surface of the glass substrate 22. ITO (Indium Tin Oxide), Tin Oxide, or the like, may be used as the transparent electrodes 24, 25. The phase difference film 14 is used as an optical anisotropic body for color compensation, and is used for compensating coloration appeared on the STN panel 20. The light source 70 is a LED (Light Emitting Diode) 71 and emits a light beam upward by a light guide 72.

[0049]

The light source 70 is constructed as shown in Fig. 7. The light guide 72 is a transparent plastic plate such as polycarbonate, acryl, or the like, having a thickness of 0.3-2 mm, and is formed with projections and recesses on the surface thereof. They are about 100 μm in size and arranged at pitches of about 200 μm, and include a projection of substantially semispherical shape as shown in Fig. 6(a), a recess of a conical shape as shown in (b), a recess of substantially semispherical shape as shown in (c), a projection in a column shape as shown in (d), a recess in a column shape as shown in (e), and so on. Density

distribution of recesses and projections in the surface may be varied so as to obtain a uniform surface intensity of the light guide 72.

[0050]

The operation of the liquid crystal display unit 10 of the present embodiment will be described in conjunction with Fig. 6.

[0051]

Under outside light, in the voltage-applied portion, a natural light beam is transformed by the polarizer 12 into a linearly polarized light in a predetermined direction and, subsequently, is passed through the STN panel 20 as the linearly polarized light as is. It is then reflected but not absorbed by the polarization splitter 40, is passed through the STN panel 20 as the linearly polarized light as is again, and emitted from the polarizer 12 as the linearly polarized light. In this manner, in the voltage-applied portion, since the light is reflected, but not absorbed by the polarization splitter 40, a display like a mirror surface may be presented.

[0052]

In the voltage-free portion, a natural light beam is transformed by the polarizer 12 into a linearly polarized light in a predetermined direction and, subsequently, is transformed by the STN panel 20 into the linearly polarized

light of which the polarizing direction is twisted by a predetermined angle, and is passed through the polarization splitter 40 as the linearly polarized light as is. The linearly polarized light that has passed therethrough is dispersed by the dispersing plate 30, and the light beam passed through the dispersing plate 30 is reflected by the reflector plate 90 and is dispersed again by the dispersing plate 30. Then, the dispersed linearly polarized light is again passed through the polarization splitter 40, is transformed by the STN panel 20 to the linearly polarized light of which the polarizing direction is twisted by a predetermined angle, and is emitted from the polarizer 12 as a linearly polarized light. The emitted light is white because it is the dispersed light.

[0053]

In this manner, in the voltage-applied portion, the light beam reflected by the polarization splitter 40 is emitted as the linearly polarized light like a mirror surface, and in the voltage-free portion, the light beam passed through the polarization splitter 40 is dispersed by the dispersing plate 30 and is emitted as a white linearly polarized light. Therefore, a display like a mirror surface on the white background is presented. In other words, the voltage-applied portion becomes dark in the directions other than the direction of outgoing angle, which is equal to the

incident angle of the light beam.

[0054]

When the light source is illuminated, in the voltage-applied portion, a linearly polarized light from the light source in a predetermined direction is passed through the polarization splitter 40, and subsequently, is passed through the STN panel 20 as is, and is absorbed by the polarizer 12. That is, the voltage-applied portion becomes black.

[0055]

In the voltage-free portion, a linearly polarized light of the light source in a predetermined direction is passed through the polarization splitter 40, and subsequently, is transformed by the STN panel 20 into a linearly polarized light of which the direction of polarization is twisted by a predetermined angle, and then is passed through the polarizer 12.

[0056]

As described above, the voltage-applied portion becomes black by being absorbed by the polarizer 12, and the light beam is emitted from the polarizer 12 in the voltage-free portion. Therefore, a black display on the background in the color of the light source is presented.

[0057]

(Second Embodiment)

Fig. 9 is an explanatory exploded cross-sectional view showing a liquid crystal display apparatus according to the second embodiment of the present invention.

[0058]

The second embodiment is the same as the first embodiment described above other than that the polarization splitter 40, the dispersing plate 30, the polarization splitter 60, and the light source 70 are arranged under the STN panel 20 in this order. The polarization splitter 60 used here is a polarization splitter described in conjunction with Fig. 3.

[0059]

Fig. 10 is a drawing showing a relation between a transmission axis of the polarization splitter 40 and a transmission axis of the polarization splitter 60. An angle formed between a transmission axis 41 of the polarization splitter 40 and a transmission axis 61 of the polarization splitter 60 is represented by θ, and the angle θ was varied.

[0060]

When the angle θ is decreased, almost all the light beam in the direction of the transmission axis 61, which has been passed through the polarization splitter 60 when the light source is illuminated, is passed through the polarization splitter 40. Therefore, both of the voltage-applied portion and the voltage-free portion become brighter. On the other

hand, when outside light is incoming, since almost all the light beam in the direction of the transmission axis 41, which has passed through the polarization splitter 40, is not reflected by the polarization splitter 60, the voltage-free portion becomes darker. In this manner, when the angle θ formed between the transmission axis 41 and the transmission axis 61 is decreased, the voltage-free portion becomes brighter in the transmissive type and darker in the reflective type. In contrast, when the angle θ formed between the transmission axis 41 and the transmission axis 61 is increased, the voltage-free portion becomes darker in the transmissive type and brighter in the reflective type. Therefore, there exist optimal values in the angle θ. As a result of an experiment, the angle θ is preferably between 45 and 80 degrees, and more preferably, between 60 and 75 degrees.

[0061]

(Third Embodiment)

A hologram which is green entirely on the surface was used as the reflector plate 90 in addition to the first embodiment. In a certain angle of view, a black display on the bright green background was presented.

[0062]

(Fourth Embodiment)

A prism sheet is used as the reflector plate 90 in

addition to the first embodiment. In a certain angle of view, a black display on the bright background was presented.

[0063]

(Fifth Embodiment)

The display apparatus according to the first embodiment of the present invention was mounted to a mobile phone. A bright display in the sun, in the shade, in the room, and in the middle of the night was presented.

[0064]

Mobile phones having the display elements according to the second to the fourth embodiments of the present invention mounted thereon, the same results were presented.

[0065]

Although the mobile phone was exemplified in the embodiments of the present invention, the display apparatus according to the present invention may be used in various electronic equipment such as electrical household appliances, PDAs (Personal Digital Assistant), electronic databooks, electric calculators, and so on.

[0066]

[Advantages]

According to the display apparatus of the present invention, under outside light, two display states including a first display state like a mirror surface formed by a light beam reflected from the second polarization splitting

unit and a second display state formed by a dispersed light beam from the light dispersing unit are presented depending on the state of the transmissive polarizing axis of the transmissive polarizing axis variable unit. In the first display state, the display becomes dark in the directions other than the direction of the outgoing angle, which is equal to the incident angle of the light beam. In the second display state, the light beam becomes a dispersing light, and thus the display is bright in all directions. When the light source is illuminated, two display states including a third display state in which the light beam is not passed through the first polarization splitting unit and a fourth display state formed by the light beam passed through the first polarization spitting unit are presented depending on the state of the transmissive polarizing axis of the transmissive polarizing axis variable unit. A bright positive display is presented in the reflecting mode in the transflective type, and a positive display is presented also in the transmitting mode.

[0067]

Preferably, a reflecting unit is provided on the opposite side of the light dispersing unit relative to the second polarization splitting unit. In this arrangement, the display becomes brighter both in the reflecting mode and the transmitting mode.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a cross-sectional view of a transflective display apparatus having a construction being interposed between two polarizers in the related art.

[Fig. 2]

Fig. 2 is a cross-sectional view of the transflective display apparatus in the related art.

[Fig. 3]

Fig. 3 is a schematic perspective view of a polarization splitter used as a polarization splitting unit in a display apparatus according to the present invention.

[Fig. 4]

Fig. 4 is an explanatory drawing showing a principle of the display apparatus according to the present invention in the reflecting mode.

[Fig. 5]

Fig. 5 is an explanatory drawing showing a principle of the display apparatus according to the present invention in the transmitting mode.

[Fig. 6]

Fig. 6 is an explanatory exploded cross-sectional view of a liquid crystal display apparatus according to a first embodiment of the present invention.

[Fig. 7]

Fig. 7 is an explanatory drawing of a light source of the liquid crystal display apparatus according to the first embodiment of the present invention.

[Fig. 8]

Fig. 8 is a drawing showing a shape of the surface of a light guide for the light source in the liquid crystal display apparatus according to the first embodiment of the present invention.

[Fig. 9]

Fig. 9 is an explanatory exploded cross-sectional view of the liquid crystal display apparatus according to a second embodiment of the present invention.

[Fig. 10]

Fig. 10 is a drawing showing a relation between a transmission axis of a polarization splitter 40 and a transmission axis of a polarization splitter 60 according to the second embodiment of the present invention.

[Reference Numerals]

10...liquid crystal display apparatus

12, 130...polarizer

14...phase difference film

20...STN panel

21, 22...glass substrate

26...STN liquid crystal

30...dispersing plate

40, 60, 160...polarization splitter

70, 190...light source

71...LED

72...back light guide

90...dispersing plate

110...voltage-applied portion

120...voltage-free portion

111, 121...natural light

112, 122...outgoing light

115, 125...light of light source

140...TN liquid crystal panel

150...light dispersing layer

200...reflecting layer

[Name of Document] ABSTRACT

[Abstract]

[Object] To provide a display apparatus using a transmissive polarizing axis variable optical element, in which a bright display is presented.

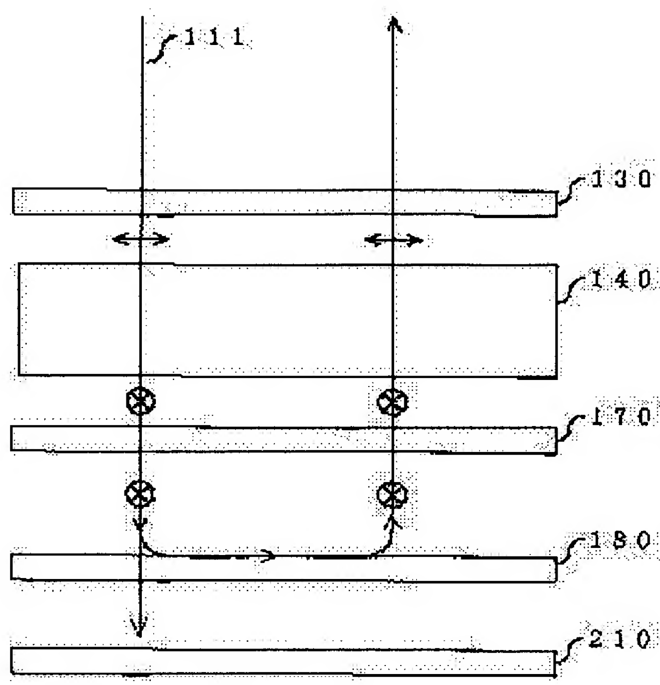
[Solving Means] A TN liquid crystal panel 140 is used as a transmissive polarizing axis varying optical element, and there is provided an upper polarizer 130 on the upper side of the TN liquid crystal panel 140. On the lower side of the TN liquid crystal panel 140, there are provided a polarization splitter 160, a light dispersing layer 150, a light source 190, and a reflecting layer 200 in this order. The polarization splitter 160 is a polarization splitter reflecting a linearly polarized light component in the direction X as the linearly polarized light in the direction X, and allowing a linearly polarized light in the direction Y, which is orthogonal to the direction X to pass therethrough as the linearly polarized light in the direction Y. Under outside light, in a voltage-applied portion 110, the light beam reflected by the polarization splitter 160 is emitted as an outgoing light 122 like a mirror surface, and in a voltage-free portion 120, the light beam passed through the polarization splitter 160 is emitted as an outgoing light 112 in white by the light dispersing layer 150. Even when the light source is illuminated, a

bright positive display as under outside light is presented.

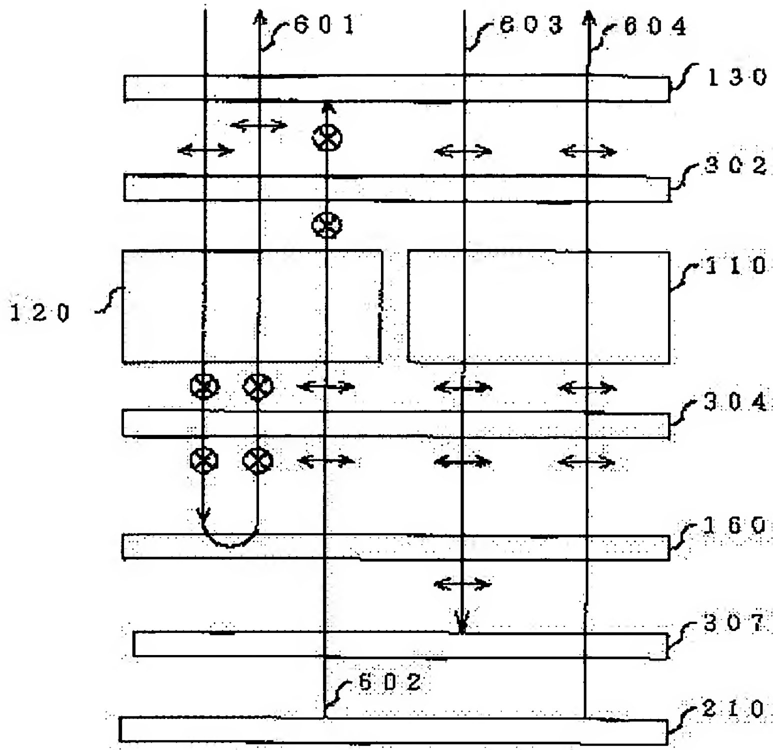
[Selected Figure] Fig. 4

【Name of Document】 Drawings

【F I G. 1】



【FIG. 2】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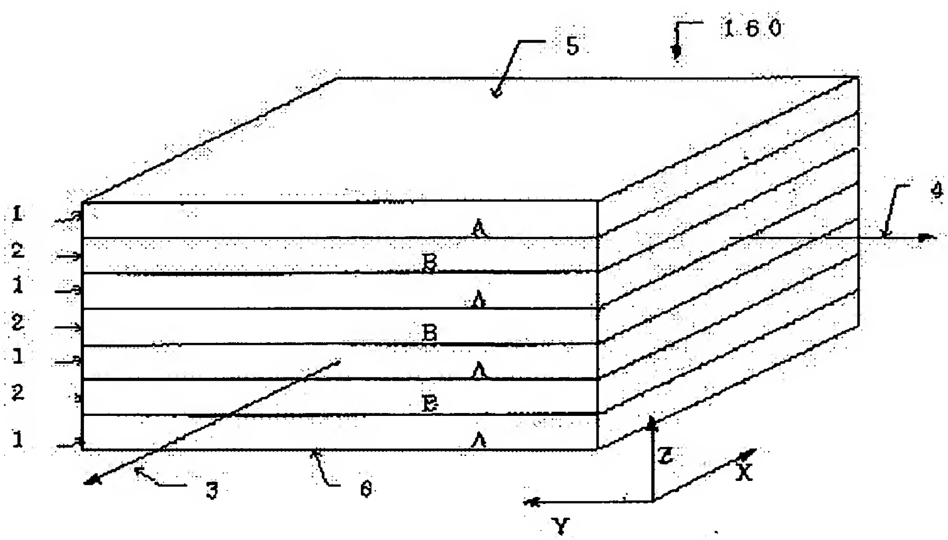
602
210

【FIG. 3】


5
160
4
1
2
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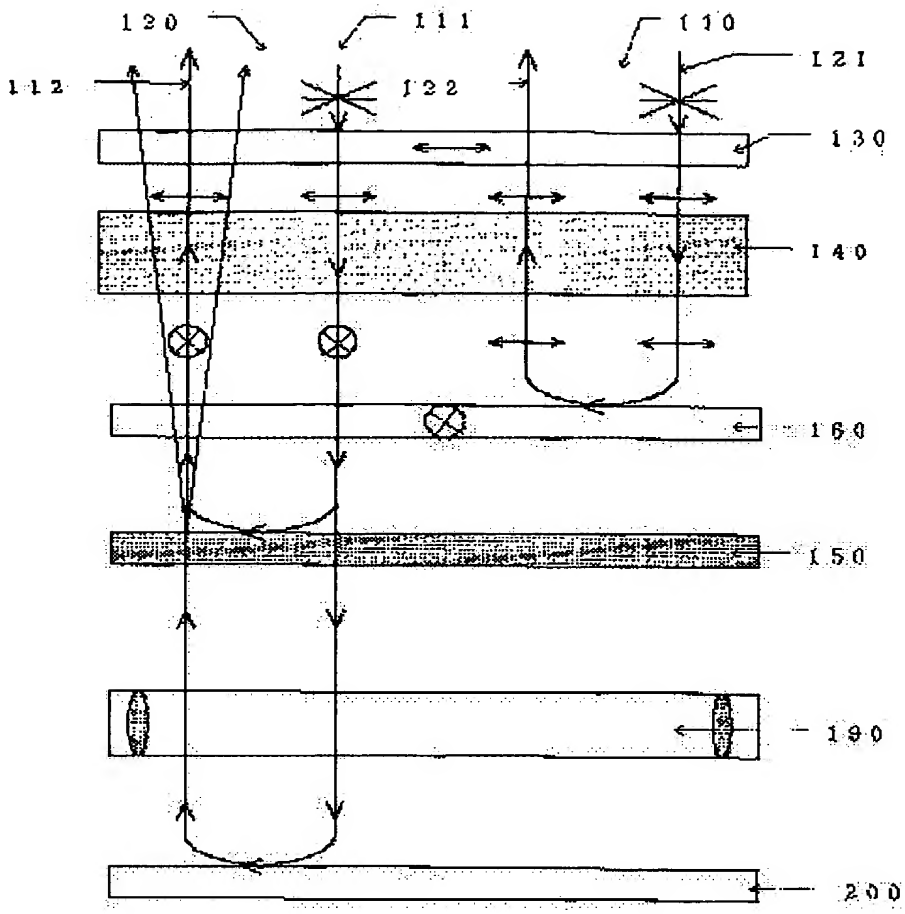
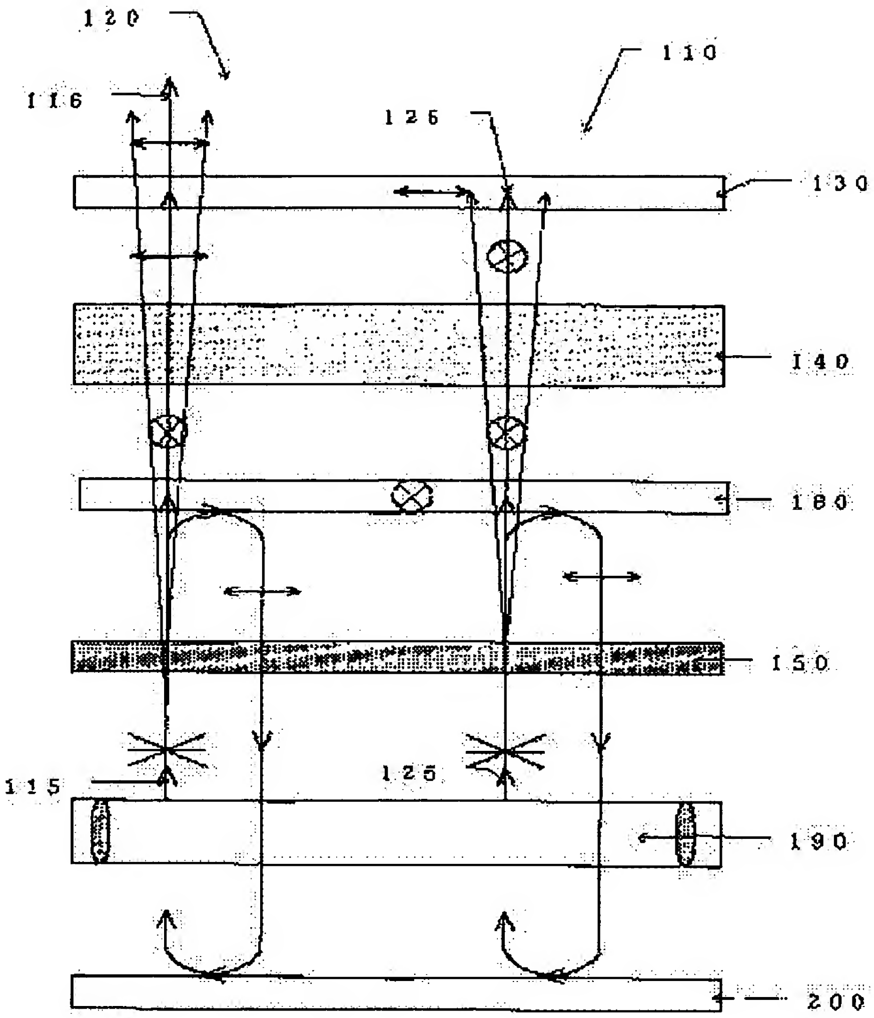
X
Y

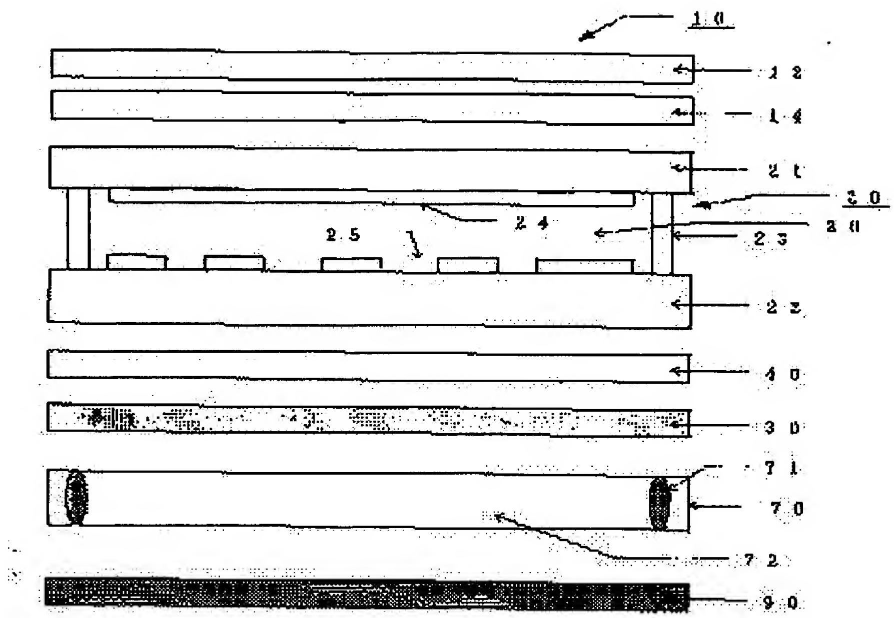
【FIG. 4】



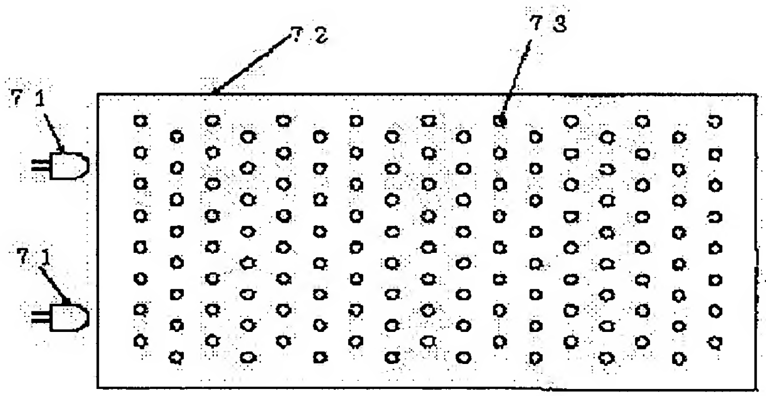
【FIG. 5】



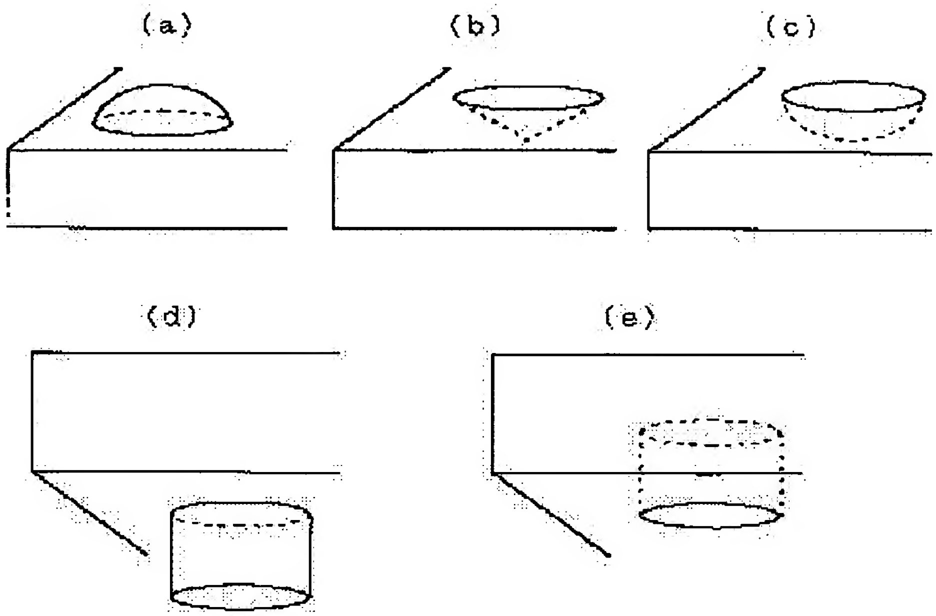
【FIG. 6】



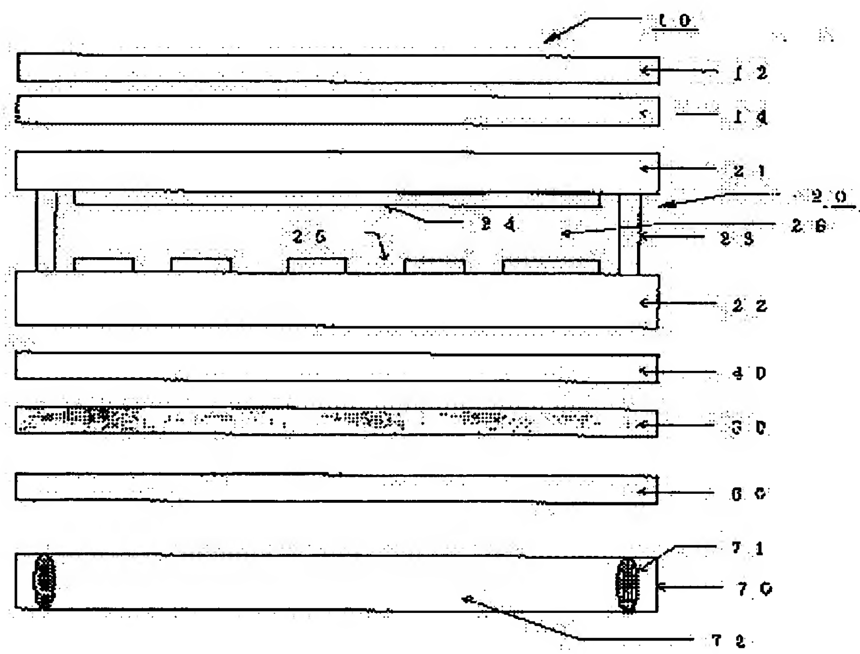
【FIG. 7】



【FIG. 8】



【FIG. 9】



【F I G. 1 0】